Announcements

- Homework for tomorrow…

  Ch. 29: Probs. 26, 29, & 60

  CQ8: a) $V_1 = V_2$ b) $Q_1 > Q_2$ c) $E_1 < E_2$
  29.14: a) E = 0 V/m b) E = -200 V/m
  29.18: L = 0.048 m
  29.38: a) E = 5 V/m b) E = -10 V/m c) E = 5 V/m

- Office hours…

  MW 10-11 am
  TR 9-10 am
  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm
  F 8-11 am, 2-5 pm
  Su 1-5 pm

Review…

- *Capacitors in parallel…*

$$\boxed{C_{eq} = C_1 + C_2 + \ldots}$$

- *Capacitors in series…*

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots}$$

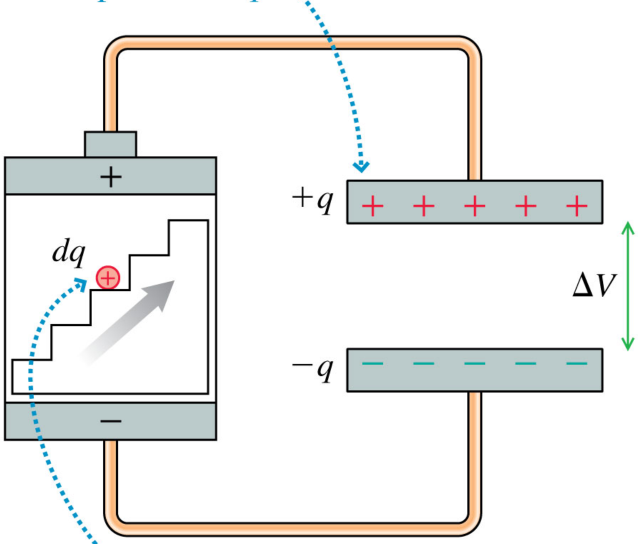
- *Capacitance…*

$$\boxed{C \equiv \frac{Q}{\Delta V_C}}$$

29.6: The Energy Stored in a Capacitor

How much *energy* is transferred from the battery to the capacitor?

The instantaneous charge on the plates is $\pm q$.



The charge escalator does work $dq\,\Delta V$ to move charge dq from the negative plate to the positive plate.

$$\text{Initially}: \; q = 0, \; U = 0$$

$$\text{Finally}: \; q = Q, \; U = U_C$$

During "charging up" of a capacitor, the potential difference across the capacitor is . . . .

$C = \frac{Q}{\Delta V} \quad \therefore \; \Delta V = \frac{Q}{C}$

"Lifting" the charge dq, through a potential difference ΔV, increases the potential energy

$dU = dq\,\Delta V$

Total energy transfered from the battery to the capacitor is . . . . .

$$\int_0^{U_c} dU = \int_0^{Q} dq\,\Delta V = \int_0^{Q} \frac{Q}{C}\,dq$$

$$U = \frac{Q^2}{2C}$$

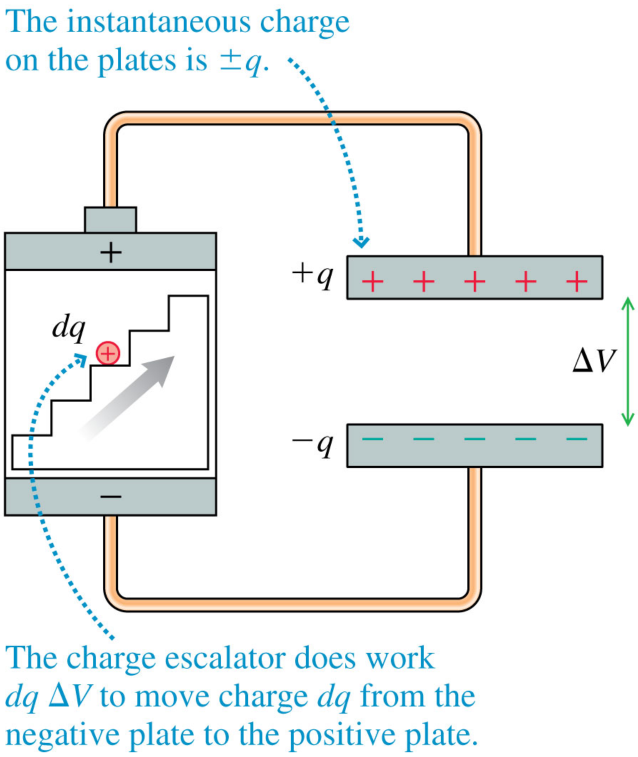
$C = \frac{Q}{\Delta V_c} \quad \therefore \; Q = C\Delta V_c$

$$U_c = \frac{1}{2C} C^2 \Delta V^2 = \frac{1}{2} C \Delta V^2$$

$$U_c = \frac{1}{2} C \Delta V^2$$

29.6:
The Energy Stored in a Capacitor

How much *energy* is transferred from the battery to the capacitor?



$$\boxed{U_C = \frac{Q^2}{2C}}$$

or

$$\boxed{U_C = \frac{1}{2}C(\Delta V_C)^2}$$

The Energy in the Electric Field

Q: If a capacitor is analogous to a stretched spring, *where* is the stored energy?

Parallel Plate Capacitor

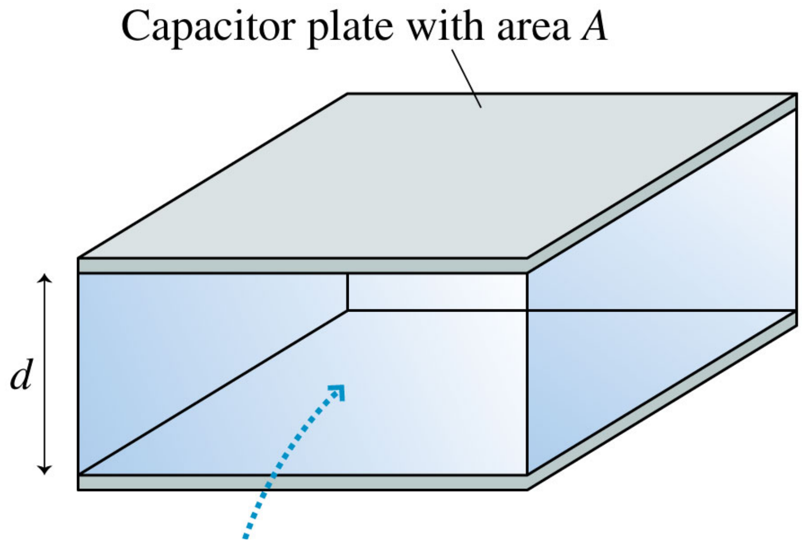
$$C = \frac{\epsilon_0 A}{d}$$

$$\Delta V_C = Ed$$

$$U_C = \frac{1}{2}\left(\frac{\epsilon_0 A}{d}\right)(Ed)^2$$

$$= \frac{1}{2}\epsilon_0 A d E^2$$

$$= \frac{1}{2}\epsilon_0 V E^2$$

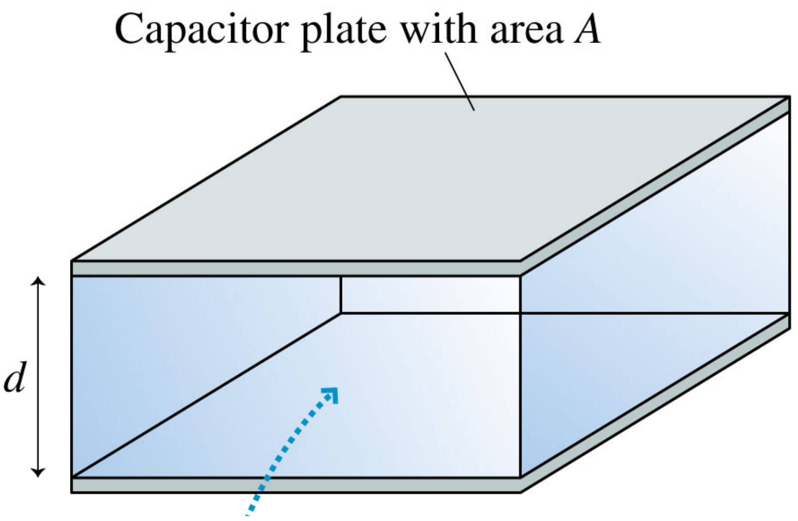


$$u_E = \frac{U_C}{Ad} = \frac{1}{2}\epsilon_0 E^2$$

$$U = \frac{1}{2}\epsilon_0 E^2$$

The Energy in the Electric Field

Q: If a capacitor is analogous to a stretched spring, *where* is the stored energy?



- A: In the E-field!

$$\boxed{u_E = \frac{1}{2}\epsilon_0 E^2}$$

$$\frac{\text{energy stored}}{\text{volume in which it is stored}}$$

When the capacitor is discharged, the energy is released as the E-field *collapses*.

Quiz Question 1

A capacitor charged to 1.5 V stores 2.0 mJ of energy. If the capacitor is charged to 3.0 V, it will store

1. 1.0 mJ.
2. 2.0 mJ.
3. 4.0 mJ.
4. 6.0 mJ.
5. 8.0 mJ.

Quiz Question 2

Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance d. Suppose the plates are pulled apart until they are separated by a distance $D>d$. The electrostatic energy stored in the capacitor is

1. greater than
2. the same as
3. smaller than

before the plates were pulled apart.

Chapter 30

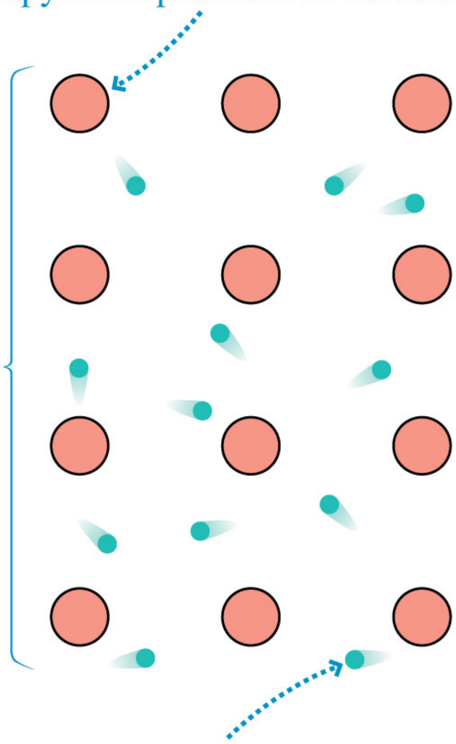
Current & Resistance

(*The Electron Current*)

30.1:
The Electron Current

Charge carriers..

- the charges that move in a conductor.
- are *electrons* in metals.
  - the outer electrons become detached from their parent nuclei to form a *sea of electrons* that can move through the solid.



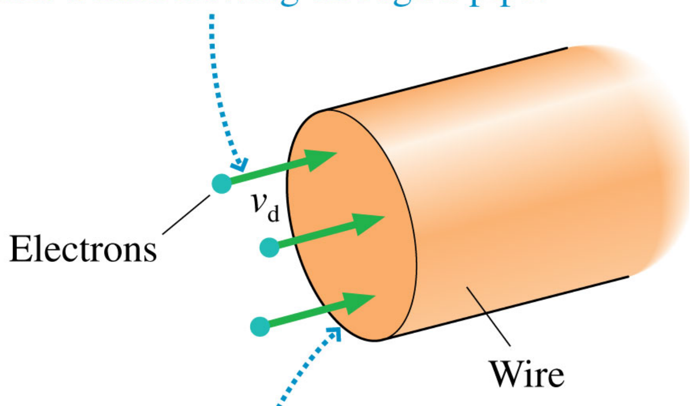
The Electron Current

Define electron current, i_e ..

- *# of electrons/second* that pass through the cross-section of the conductor.

- The number N_e of electrons that pass through the cross-section during the time interval Δt is

$$N_e = i_e \Delta t$$

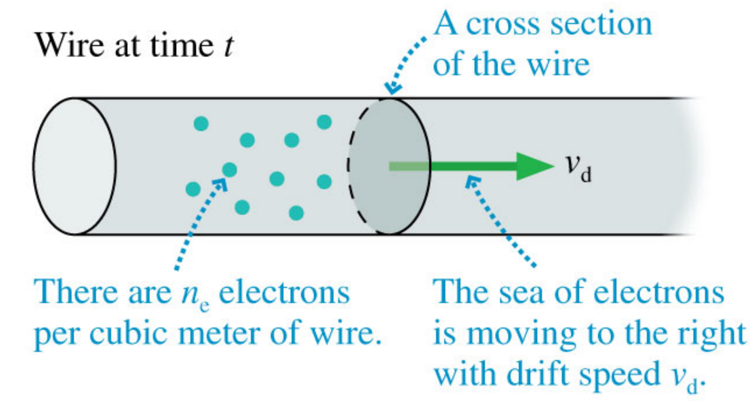


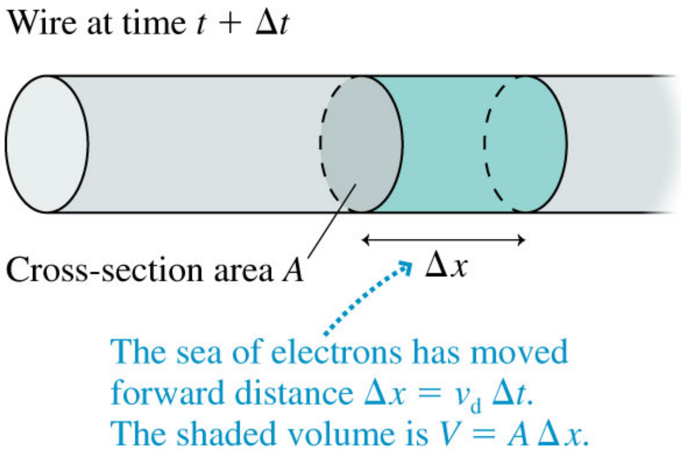
$i_e = \frac{N_e}{\Delta t}$ $\quad i_e = s^{-1}$

$N_e = i_e \Delta t$

The Electron Current

The electron current, i_e , in terms of the *drift velocity*, v_d, & the *number density*, n_e, is…





number density, n_e, - - - - -

$n_e = \frac{N_e}{V}$ $\quad n_e = 10^{28}\ m^{-3}$

$N_e = n_e V$

$V = A\Delta x$

$\therefore \Delta x = v_D \Delta t$ $\quad V_D$ = Drift speed

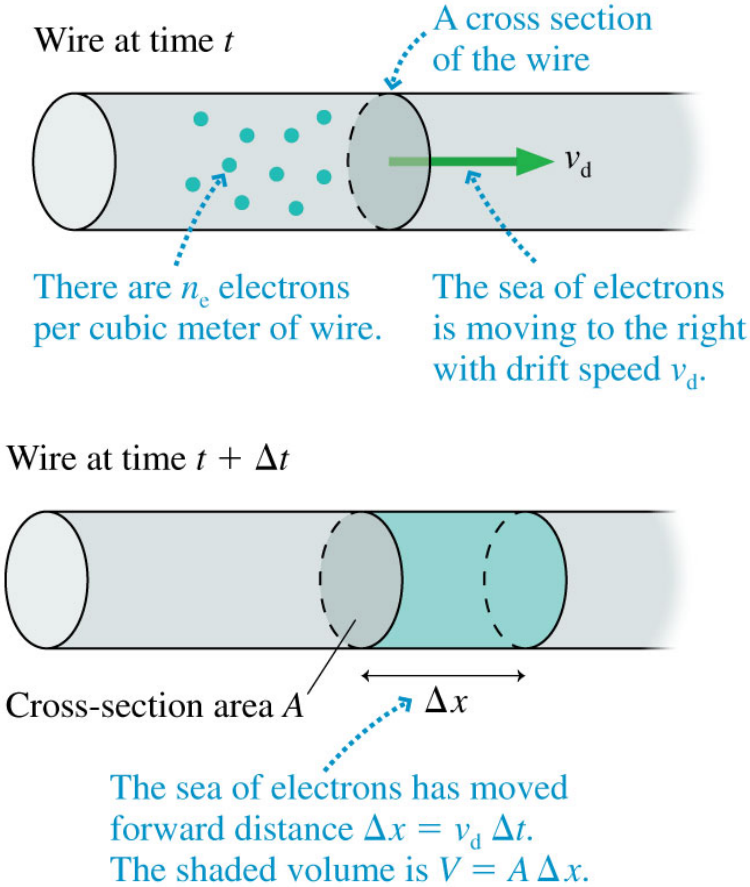
$N_e = n_e A v_D \Delta t = i_e \Delta t$

$i_e = n_e A v_D$

The Electron Current

The electron current, i_e , in terms of the *drift velocity*, v_d, & the *number density*, n_e, is…

$$\boxed{i_e = n_e A v_d}$$



Quiz Question 1

The electron drift speed, v_d, in a typical current-carrying wire is

1. Extremely slow ($\sim 10^{-4}$ m/s).
2. Moderate (~ 1 m/s).
3. Very fast ($\sim 10^{4}$ m/s).

Quiz Question 2

A wire carries a current. If both the wire diameter and the electron drift speed are *doubled*, the electron current increases by a factor of

1. 2.
2. 4.
3. 6.
4. 8.
5. Some other value.

i.e. 30.1:
The size of the electron current

What is the electron current in a 2.0 mm diameter copper wire if the electron drift speed is 1.0×10^{-4} m/s?

Given: $n_e = 8.5 \times 10^{28}$ m^{-3} for copper.